Hadron Collider Physics Symposium (HCP2008), Galena, Illinois, USA

Search for High-Mass Resonances Decaying into Leptons of Different Flavor ($e\mu$, $e\tau$, $\mu\tau$)

Yanjun Tu
University of Pennsylvania, Philadelphia, PA 19104, USA

We present a search for high-mass resonances decaying into two leptons of different flavor: $e\mu$, $e\tau$ and $\mu\tau$. These resonances are predicted by several models for Physics Beyond the Standard Model, such as R-parity-violating MSSM. The search is based on 1 fb^{-1} of Tevatron Run II data collected with the CDF detector at $\sqrt{s} = 1.96$ TeV in proton anti-proton collisions.

1. Introduction

One of the most promising theories for Physics Beyond the Standard Model is Supersymmetry. In the minimal supersymmetric exstension of the SM, the MSSM, an additional quantum number, defined as

$$P_R = (-1)^{3(B-L)+2s} \tag{1}$$

is introduced. SM particles carry R-parity of 1 while supersymmetric particles have R-parity of -1. R-parity violating (RPV) decays can happen through the following interaction terms:

$$\begin{aligned} W_{\Delta \mathrm{L}=1} &= \frac{1}{2}\lambda^{ijk} L_i L_j \bar{e}_k + \lambda^{'ijk} L_i Q_j \bar{d}_k + \mu^{'i} L_i H_u, \\ W_{\Delta \mathrm{B}=1} &= \frac{1}{2}\lambda^{''ijk} \bar{u}_i \bar{d}_j \bar{d}_k \end{aligned} \tag{2}$$

where the indices i, j and k denote the generations. The fields in Eq. 2 are superfields [1]. The 48 RPV couplings in Eq. 2 are constrained from theoretical and phenomenological points of view ([2], [3]).

The DØ Collaboration searched for heavy sneutrino decaying into $e\mu$ in 1.0 fb^{-1} of data [4]. The previous search for high-mass resonances decaying into $e\mu$ channel by the CDF Collaboration used 344 pb^{-1}[5].

In SUSY models, with an extra $U(1)'$, lepton flavor violation (LFV) interactions are allowed by the Lagrangian density: $\frac{\mathrm{g}'_\mathrm{z}}{\sin\theta_\mathrm{W}}[\bar{\psi}_\mathrm{i} \mathrm{Q}^{\psi}_{\mathrm{ij}} \gamma^\mu \psi_\mathrm{j}] \mathrm{X}_\mu$, where i, j are generation indices, g'_Z is the $U(1)'$ gauge coupling, $\sin\theta_W$ is electroweak mixing angle and Q^{ψ}_{ij} is referred to as the "charges" [6]. The lepton charges Q^l_{ij} are constrained by low energy experiments [7]. CDF Run II performed a search for $p\bar{p} \to Z' \to e\mu$ and excluded a portion of the Q^l_{12} vs.$M_{Z'}$ plane [5].

2. Event Reconstruction

We use CDF Run II data corresponding to an integrated luminosity of 1 fb^{-1}. We select events with two identified leptons of different flavor and opposite electric charge. To distinguish the flavor, we select only hadronic taus. The kinematic cuts of the leptons are the following: electron $\mathrm{E_T} \geq$ 20 GeV, muon $\mathrm{P_T} \geq$ 20 GeV/c and tau visible $\mathrm{E_T} \geq$ 25 GeV. Candidate events in $e\mu$ channel and $e\tau$ channel are collected by the high$-\mathrm{p_T}$ single electron trigger path, which requires an electron candidate with $\mathrm{E_T} \geq$ 18 GeV and with pseudorapidity $|\eta| \lesssim 1.1$. Candidate events in $\mu\tau$ channel are collected by the high$-\mathrm{p_T}$ single muon trigger path, which requires a muon candidate with $\mathrm{P_T} \geq$ 18 GeV/c and pseudorapidity $|\eta| \lesssim 1.0$. Lepton candidates above the kinematic threshold are required to pass lepton identification cuts. In this analysis, we select muons which pass through CMUP ($|\eta| \lesssim 0.6$) and CMX ($|\eta| \lesssim$

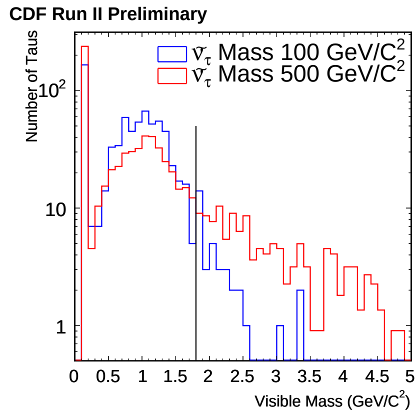

Figure 1: The visible mass distribution of τ's from 500 GeV/c^2 $\widetilde{\nu}_\tau$ decay is broader than the distribution of τ's from 100 GeV/c^2 $\widetilde{\nu}_\tau$ decay. The fixed mass cut ($<$ 1.8 GeV/c^2) is not efficient for high-energy τ's.

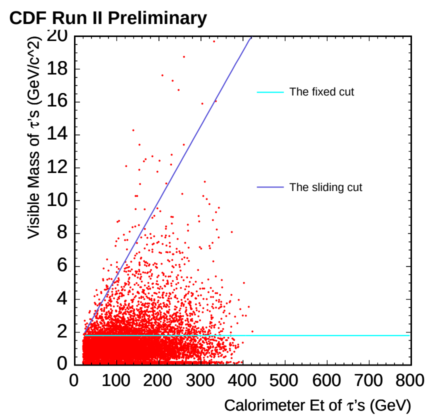

Figure 2: The sliding visible mass cut as a function of τ energy (dark blue line) and the fixed visible mass cut (light blue line). The τ's between the dark blue line and light blue line are recovered.

1.0) muon detectors [9]. They are required to pass the standard CDF muon ID cuts [10]. Electron and hadronic tau reconstruction and identification algorithms have been improved to increase the acceptance at large lepton energy. A standalone calibration of the Central Showermax detector (CES) [9] has been performed, providing a better resolution of the shower energy. As a consequence, the ID efficiency of electrons improved by $\sim 10\%$ (Figure 3). It also improves the energy measurement of π^0 contributing to the visible momentum of the hadronic tau [1].

As shown in Figure 1, the efficiency of the standard fixed upper cut on the tau mass ($<$ 1.8 GeV/c^2) decreases as the energy of the tau increases. The fixed cut on tau visible mass (mass of the π^0s and tracks originating in the tau decay) is replaced by an energy dependent cut (Figure 2). The upper cut is selected to yield a constant 95% efficiency when energy of the tau increases.

Tau quantities related to the hadronic shower are poorly simulated and therefore tuned to data.

Due to the improvements described above, the ID efficiency of τ improved by factor of 2 (Figure 3).

[1] We reconstruct hadronic taus through their decay products. Tracks from charged particles ($\pi^\pm$ and $K^\pm$) are reconstructed by the Central Outer Tracker (COT); neutral pion (π^0) energies and positions are measured by the Calorimeter and Central Showermax Detector (CES). We measure π^0 energy using the calibrated CES energy measurement.

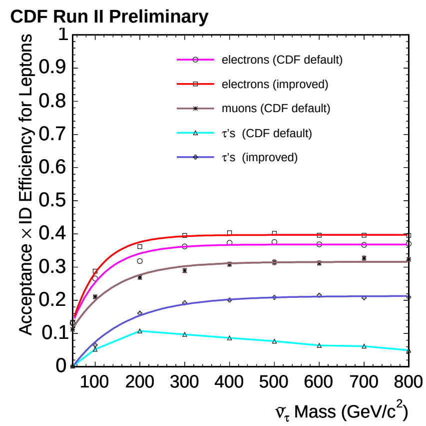

Figure 3: τ ID efficiency decreases when energy of τ increases if we use CDF default ID (light blue). The ID efficiency of the τ keeps constant in the high energy region by using the new ID (dark blue). In addition, τ ID efficiency has been improved by factor of 2 by using the new ID. The ID efficiency of electron has been improved by $\sim 10\%$ by using the new ID.

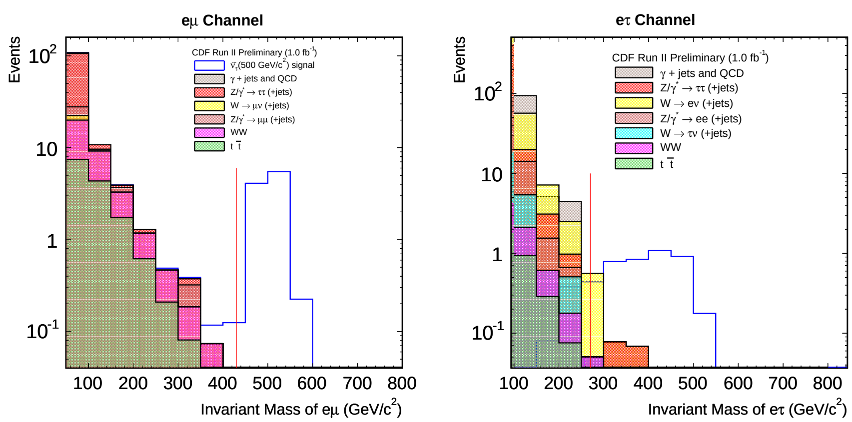

Figure 4: Dilepton mass distributions for SM background and expected signal in eμ and eτ channels.

3. Standard Model Backgrounds

There are several SM processes having the same signature as the signal: Drell Yan ($Z/\gamma^* \to \tau\tau$), diboson (WW) and $t\bar{t}$. There are also backgrounds due to mis-identified leptons. We consider W+jet(s) and Drell Yan+jet(s), where the gauge boson leptonically decays into e/μ/τ and a jet is mis-identified as a lepton. In addition, leptons from Drell Yan ($Z/\gamma^* \to ee$, $Z/\gamma^* \to \mu\mu$) can be mis-identified; typically the electron is mis-identified as tau and the muon is mis-identified as electron or tau. These backgrounds are estimated using PYTHIA Monte Carlo samples. The PYTHIA event generator with CTEQ5L parton distribution function (PDF) and the CDF run II detector simulation based on GEANT 3 are used to generate the simulated samples.

Along with the backgrounds listed above, QCD events with jets faking either leptons, or with one jet faking a lepton (muon, tau) and one γ faking an electron are background to the signal. To estimate this background, we use events with same charge in data since there is no correlation between the charge of the leptons in dijet and γ+jet events. We need to subtract the contribution of same charge events originating from the backgrounds other than dijets and γ + jets.

The background estimates in whole mass region are shown in Fig 4.

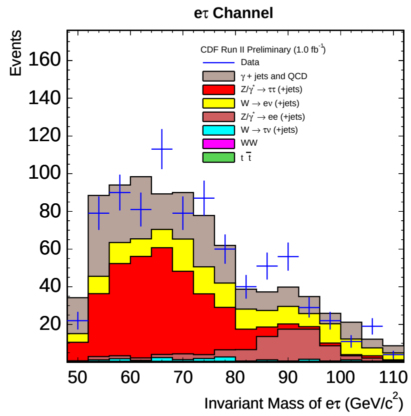

Figure 5: Dilepton (eτ) mass in the eτ channel control region.

4. Control regions

We check the consistency between the expectations from SM backgrounds and data in the control region defined as: 50 GeV/c^2 < dilepton mass $\mathrm{M_{LL}}$ < 110 GeV/c^2 (for instance, Fig 5). To estimate the number of expected SM events, we use the same selection as applied to the data. The events selected in the Monte Carlo background samples are scaled by the lepton ID scale factors and the trigger efficiencies.

5. Conclusions

We performed a search for high-mass resonances decaying into two leptons of different flavor: $e\mu$, $e\tau$ and $\mu\tau$. The search is based on 1 fb^{-1} of Tevatron Run II data. We first improved electron ID efficiency and tau ID efficiency. We find agreement between the SM prediction and observation in data in the control regions.

Acknowledgments

We thank the organizer of 2008 HCP conference for providing us a chance to show the analysis. We also thank the CDF Collaborations for their hard work which makes the results possible.

References

[1] S. P. Martin, arXiv:hep-ph/9709356.
[2] M. Chemtob, Prog. Part. Nucl. Phys. **54**, 71 (2005) [arXiv:hep-ph/0406029].
[3] F. Ledroit and G. Sajot , Indirect limits on SUSY R_p violating couplings λ and λ' GDR-S-008
[4] V. M. Abazov *et al.* [D0 Collaboration], Phys. Rev. Lett. **100**, 241803 (2008) [arXiv:0711.3207 [hep-ex]].
[5] A. Abulencia *et al.* [CDF Collaboration], Phys. Rev. Lett. **96**, 211802 (2006) [arXiv:hep-ex/0603006].
[6] P. Langacker and M. Plumacher, Phys. Rev. D **62**, 013006 (2000) [arXiv:hep-ph/0001204].
[7] B. Murakami, Phys. Rev. D **65**, 055003 (2002) [arXiv:hep-ph/0110095].
[8] T. Han and D. Marfatia, Phys. Rev. Lett. **86**, 1442 (2001) [arXiv:hep-ph/0008141].
[9] The CDFII Collaboration, "The CDF Detector Technical Design Report",. FERMILAB-Pub-96/390-E.
[10] A. Abulencia et al., The CDF Collaboration, J. Phys. "Measurements of Inclusive W and Z Cross Sections in p anti-p Collisions at s**(1/2) = 1.96 TeV" G: Nucl. Part. Phys. (2007) 2457-2544